Design of Road Geometric with AutoCAD® 2D: A Case Wirosari-Ungaran Semarang, Indonesian

1Dimas Sukma Adiputra, 2Andri Irfan Rifai, 3Surya Kencana Bhakti
1Faculty of Engineering, Universitas Mercu Buana, Indonesia
2Faculty of Civil Engineering & Planning, Universitas Internasional Batam, Indonesia
3Directorate General of Highway, Ministry of Public Works & Housing, Indonesia
E-correspondence: dimassukma999@gmail.com

Copyright © 2022 The Author

This is an open access article
Under the Creative Commons Attribution Share Alike 4.0 International License

DOI: 10.53866/jimi.v2i5.186

Abstract

The geometric design of the road Wirosari Semarang to Ungaran road section, which is in the city of Semarang, is one of the infrastructures to provide proper road access with optimal travel time. With the division process, the government must provide proper road access with optimal travel time so that the community mobilization process can run smoothly. The research objective is to plan the geometric shape of the road according to the applicable requirements to provide safety and comfort for road users. The Highway Road Geometric Rule method and visualization using AutoCAD® 2D are used. The results of the geometric planning of the road are obtained with a design speed (Vd) of 60 km/hour, a planned road width of 2 x 3.5 meters, and a road alignment with a horizontal curved Spiral Circle Spiral with a radius of 318 m is formed. Meanwhile, the vertical alignment obtained a concave arch type with a length value (L) of 53.28 m

Keywords: Autocad®, Horizontal Alignment, Road Geometric, Vertical Alignment.

1. Introduction

Roads are critical infrastructures that serve as the backbone of any country and enable fast and safe shipments (Palilu, 2022). Road construction as an effective and reliable transportation infrastructure in the form of an integrated transportation system will provide services and benefits for the wider community, economic development, and ease of mobility (Costin, Adifbar, Hu, & Chen, 2018). Around the world, the European continent recorded around 139 million kilometers traveled and 632,186 vehicles widely monitored, being one of the datasets for opportunities to shape the future of road transport. (Paffumi, De Gennaro, & Martini, 2018). This high figure must be balanced with the addition of existing road lanes to fulfill the support for community mobilization.

Indonesia currently has a population of more than 230 million people, and the country's economic growth has driven an ever-growing increase in transportation. (Soehodho, S., 2017). Road geometric design is part of road design that is focused on designing the physical form of the road in such a way as to produce a road shape that can be utilized for traffic operations quickly, smoothly, safely, comfortably, and efficiently. (Gaikawad & Ghodmare, 2020). The basis of geometric road design is topography, geology, land use, movement characteristics, vehicle size, and traffic characteristics (O'Flaherty, 2018). This becomes material for planning consideration to produce a shape and size of road that meets the level of comfort and safety (Shi, Fonseca, & Schlueeter, 2017). In addition, an efficient road network is close to the basic principles of geometric road planning (Heinimann, 2017).

Semarang City is the capital of Central Java Province, where population growth is increasing yearly. As the capital of the province, the city of Semarang is required to meet and guarantee its population's needs (Hardati & Setyowati, 2019). This encourages the urbanization of the population and expansion of the
region in the city of Semarang (Arsandi, Ismiyati, & Hermawan, 2017). With the division process, the government must provide proper road access with optimal travel time so that the community mobilization process can run smoothly. Winding roads and contours are a timely process in building a road. A highway geometric design related to an authentic physical design can make it easier for sustainable road development (Veer, Gupte, & Juremalani, 2018). In geometric road planning, several planning parameters must be understood, such as design vehicles, design speed, road volume and capacity, and the road's level of service. (Pilko, Mandžuka, & Barić, 2017).

AutoCAD® is software or software for drawing two-dimensional and three-dimensional shapes (Ingale, Srinivasan, & Bairaktarova, 2017) . The application of AutoCAD® technology in highway surveying and design has led to major changes in traditional highway design methods. This has contributed to the technological progress of the road transport industry and has become one of the main signs of the modernization of road surveying and design (Fan & Huang, 2022). However, the use of several other software can produce design and calculation functions to achieve maximum results. Therefore, increasingly advanced technology is hoped to increase the accuracy of calculations and efficiency to reduce design costs and planning costs (Asamadu, Zhang, Zhao, Osei-Wusuansa, & Akoto, 2019).

The existence of this planning technology of which can reduce congestion, increase travel time, and increase the economy (Abduljabbar, Dia, Liyamage, & Bagloee, 2019). This study evaluates the influence of horizontal curve geometry on the distribution of vehicle speeds for four-lane divided highways. It develops a prediction model for the average speed and standard deviation. (Sil, Nama, Maji, & Maurya, 2020). This study plans a road on this segment with a vertical, and horizontal curve to provide safety and comfort for road users (Akgün-Tanbay, Campisi, Tanbay, Tesoriere, & Dissanyake, 2022). Besides that, another goal is to optimize alignment on the highway (Li, Ding, & Zhong, 2019). Based on the problems above, a redesign will be carried out on the existing road, precisely on the Wirosari-Ungaran Semarang Sta. 0+000 – Sta. 20+500 by making horizontal alignment and vertical alignment at Sta. 15+000 - St. 17+000 along 2.0 km with manual calculations and using autoCAD® 2D. This research is expected to be a solution for effective and efficient road geometric design.

2. Literature Review

2.1. Highway

Roads are land transportation infrastructure covering all parts of the road, including complementary buildings and equipment intended for traffic, which are at ground level, above ground level, below ground and or water level, and above water level, except railways: fire, lorry, and a cableway. Public roads are roads designated for general traffic. Public roads are implemented by prioritizing the construction of a road network in production centers and roads connecting production centers to marketing areas. According to their status, public roads are grouped into; national roads, provincial roads, district roads, city roads, and village roads.

The highway is a means or place for vehicles to pass, whether motorized vehicles or the like, that pass through the road. because the highway is a very important means that influence all aspects of life. From any point of view, the highway is the driving force of an economy and the progress of a country (Olayode, Tartibu, & Okwu, 2020) . In addition, roads are land transportation infrastructure that plays a significant role in the transportation sector, especially for the continuity of the distribution of goods and services.

Traffic in Law No. 22 of 2009 is defined as the movement of vehicles and people in the road traffic space, and what is meant by road traffic space, road traffic space, namely infrastructure intended for the movement of vehicles, people, or goods in the form of supporting facilities. The government aims to realize safe, secure, smooth, orderly, and efficient road traffic and transportation through traffic management and traffic engineering.

2.2. Geometric design

Road geometric planning is part of road planning which is focused on planning the physical form of
the road. The purpose of geometric road planning is to fulfill the essential function of the road, namely, to provide services for the movement of traffic flows (vehicles) in an optimum manner. The goal of geometric road planning is to produce a safe and efficient road infrastructure design that serves traffic flow and maximizes the ratio of usage rates and implementation costs.

The basis of geometric planning is the vehicle's nature, movement, and size of the vehicle, the nature of the driver in controlling the vehicle, and the traffic flow characteristics. The highway geometric elements are obtained through several analyzes and calculations that are selected and positioned in such a way as to meet the requirements. These things must be considered by the planner so that the resulting shape and size of the road and the movement of vehicles meet the expected level of comfort and safety. A balanced road planning and design approach can improve operational efficiency, driving safety, and public facilities while minimizing environmental impacts, including noise, vibration, pollution, and visual disturbances. (Fanning, Veith, Whitehead, & Auman, 2021). Furthermore, the precise geometric design can reduce the accident and damage rates (Chakole & J.Wadhai., 2022). Therefore, the planning and design of the geometric features of the road, including the planning of horizontal alignment, vertical alignment, calculation of visibility distance, and determination of horizontal and vertical curvature radii, must be carried out carefully.

2.3. Horizontal and Vertical Alignment

Horizontal alignment is mainly focused on road axis planning. In horizontal alignment planning, it will be seen whether the road is straight, bends to the left, or the right. The axis of the road consists of a series of straight lines, circular curves, and transitional curves from straight lines to circular arcs. Horizontal curvature is one of the most critical aspects affecting road efficiency and safety. Poor design will result in lower speeds and a resulting reduction in road performance in terms of safety and comfort (Sukalkar & Pawar, 2022)

Vertical alignment is the intersection of the vertical plane with the pavement surface plane through the axis of the road for 2-lane 2-way roads or through the inner edge of each pavement for roads with a median (Putri, Nanda, & Aminsyah, 2021). Vertical alignment is also called the longitudinal section of the road, consisting of straight and curved lines. Planning a cross-section of the road is one part of the geometric planning of the road. Of course, they charged with safe and economic terms. In addition, vertical alignment planning must always consider the condition of the subgrade, flood water level, groundwater level, road function, slope, and terrain conditions.

To plan horizontal alignment and vertical alignment, integration between the requirements and the applicable parameters must be carried out. For example, a horizontal curve refers to how straight a road segment is, while a vertical alignment refers to the elevation of a pavement or the level of a road. (Latif, 2022). The process of combining vertical and horizontal alignments must be able to produce a road design that meets safety requirements and can be realized in the field. Several factors determine the alignment, such as the type of contour or topography of the area in question, watersheds, and environmental, social, and economic considerations for sustainability in aligning road geometries.

2.4. AutoCAD®

AutoCAD® is a software developed in the early 1980s by Autodesk incorporation that is used for constructing objects in a graphical display. (Jimoh, 2019). AutoCAD has an essential role in helping to simplify and help visualize the results of planning an object into a graph or image that many people easily understand. In addition, using several other software can produce design and calculation functions to achieve maximum results. Therefore, with increasingly advanced technology, it is hoped that it will increase the accuracy of calculations and efficiency.

Currently, AutoCAD® is currently geared towards using computer programs for road geometry design. The programs offer incredible precision and save a lot of time and effort. This paper presents a complete geometric design unique to the highway using AutoCAD® Civil 3D software (Mandal, Pawade, Sandel, & Infrastructure, 2019). In addition to visualizing buildings, AutoCAD® also aims to
demonstrate how geometric designs can be carried out quickly and accurately in a short time for road design planning. 

AutoCAD® has an essential role in helping to simplify and help visualize the results of good planning. An object can be a graphic or an image that many people easily understand. This software is multi-functional in various fields and can combine aspects such as architecture, structure, and construction to make it easier for workers to realize a design. In this modern world, computerization is commonplace, and the use of AutoCAD® is equally essential for every engineer in planning and visualization.

2.5. **Sight distance**

Overtaking visibility is reduced from the minimum length required for vehicles to pass safely. The provision of overtaking visibility reduces the effect of slowing down other vehicles, especially when the vehicle is heavy with steep ascents and descents. In contrast to the viewing distance, the viewing distance, the infrequent view of the pass is not an important criterion. (Mahanpoor, Monajjem, & Balali, 2021). Five basic types of sight distances must be considered in the design, namely: sight distance at the stop, sight overtaking, decision sight, pre-view distance (on a horizontal curve), and sight distance at the intersection. Therefore, planning the visibility must follow the planned criteria. According to (AASTHO, 2018), based on the distance traveled to the critical position of the forward movement, theoretically, it is attempted to approach the natural state.

This visibility is determined by several factors, such as the height of the driver's eye above the road surface, the height of particular objects above the road surface, and the height of objects in the lateral position of obstructions in the driver's line of sight. For example, on a contoured road which is a barrier to the driver's visibility, it occurs at several points at the top of a vertical curve. In contrast, on a horizontal curve it is a barrier to visibility for trees, retaining slopes, and several other objects besides the road.

3. **Methodology**

Road geometric planning uses a design age of 20 years with existing data collected by collecting research data from researchers, journal data, and to related agencies/agencies from the Public Works Office and the Semarang City Transportation Service. The data obtained is then processed and analyzed according to the calculations used by quantitative and qualitative methods. The geometric planning of this road is a plan to start from Jalan Raya Wirosari Semarang to the eastern part of Ungaran Square. This new road plan is an access in the southern part of Semarang City to Semarang Regency along 20.1 kilometers.

![Figure 1. Location of study](https://journal.das-institute.com/index.php/citizen-journal)

A road work construction plan needs some supporting field data to obtain a safe and efficient
construction design. The systematic scientific research process must begin with identifying the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). Quantitative and qualitative methods are used for the geometric planning criteria for this road. Quantitative research methods are sourced from mathematical sample data to obtain road geometric planning results according to standards. Understanding data is one of the main strengths in compiling research and scientific modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015). The data required is Secondary Data.

Secondary data is obtained through the sources concerned without conducting research or observation first. The secondary data compiling this report include Average Daily Traffic (ADT-LHR). In addition, the guideline for standard provisions used in this study was carried out through manual calculations based on road geometric planning criteria by the Circular Letter of the Ministry of Public Works and Public Housing of the Director General of Highways concerning the 2021 Road Geometric Design Guidelines. The results of the geometric road design will then be visualized in pictures. using AutoCAD® 2D. The data obtained follow the plan in the research so that it is precise and appropriate. (Rifai, Surgiarti, Isradi, & Mufhidin, 2022).

4. Result and Discussion

The following is the geometric alignment plan for Jalan Raya Wirosari Semarang to Ungaran using the Road Geometric Guidelines (Ditjen Bina Marga, 2021), which is equipped with the steps taken and the standards used.

4.1. Horizontal alignment

The following data is obtained from Jalan Bukit Kencana Jaya Wirosari Semarang to Ungaran for calculating horizontal alignment (Spiral - Circle - Spiral). Design criteria for the Wirosari to Ungaran highways which are classified as Primary Collector Roads with Road Class IIIA and on flat terrain, the design speed range (VD) is obtained between 60 – 100 km/hour as stated in Table 5.1 in the Road Geometric Planning Guidelines (Ditjen Bina Marga, 2021).

Therefore, the design speed (VD) is taken as 60 km/hour. Based on Table 5.2 (p.45) with VD = 60 km/hour, the maximum superelevation value (Emax) is 10%, and in the graph in Figure 5-17 (p.96), the transverse roughness factor value is taken as 0.17. the value of β is known to be 20°, and the superelevation slope (e) is 8% with a road width of 2 x 3.50 m and a design radius (Rc) of 318 m. So that the minimum radius value for horizontal curves can be calculated as follows, calculating the minimum radius (R min) can use equation (1). Meanwhile, can calculate F max successively through equation (2) as follows.

\[
R_{\text{min}} = \frac{V^2}{127 \left( \frac{e \text{ maks} + f \text{ maks}}{60^2} \right)} = \frac{60^2}{127 \left( 0.08 + 0.153 \right)} = 112 \text{ m}
\]

Because V<80 km/hour, use the following formula.

\[
F_{\text{max}} = -0.0065v + 0.192
\]

After obtaining the design radius (R), we can calculate the Transition Arch Length (Ls) based on the design speed (Vd) of the travel time, where the value of the travel time (T) is 3 seconds with the following formula:

\[
Ls = \frac{V_d}{3.6} \times T
\]

The minimum transition arc (Ls) can also be determined using table 5-32 (p.114), based on the value R=318 m; gold = 8%; with a road width of 3.50 meters and 2 lanes, the value Lsmin = 23 m is obtained. Then it can be taken that the largest value of Ls is Ls = 50m and e = 0.059
Next, calculate the properties of the horizontal curve (θs) by knowing the magnitude of the transition curve (Ls) and the design radius (Rc) as follows.
\[
\theta_s = \frac{\pi \cdot Rc}{\pi \cdot 318} \quad \text{(4)}
\]
\[
\theta_s = \frac{90 \cdot Lc}{\pi \cdot 50} = 4,504^\circ
\]

Next, calculate the circle angle (θc) by knowing the value of the beta coefficient (β) and horizontal curve (θs). After that calculate the curved length of the plan (Lc).
\[
\theta_c = \beta - 20s 
\quad \text{..................................................................................................................(5)}
\]
\[
\theta_c = 20^\circ - (2 \times 4,504^\circ) = 10,99^\circ
\]
\[
Lc = \frac{\theta_c}{360} \times 2\pi Rc 
\quad \text{..................................................................................................................(6)}
\]
\[
Lc = \frac{10,99^\circ}{360} \times 2\pi 318 = 61,007 \text{ m}
\]

Check Lc > 20 m , 61,007 m > 20 m ...(OK)

Calculating the total length (L) by knowing the value of the length of the design curve (Lc) and transitional curve (Ls)
\[
L = Lc + (2 \times Ls) \quad \text{..................................................................................................................(7)}
\]
\[
L = 61,007 \text{ m} + (2 \times 50) = 161,007 \text{ m}
\]

Determine the friction tangent to the spiral (P) and the abscissa of p on the spiral tangent line (K) as follows.
\[
P = \frac{Ls^2}{6Rc} - Rc (1 - \cos \Theta s) 
\quad \text{..................................................................................................................(8)}
\]
\[
P = \frac{50^2}{6 \times 318} - 318 (1 - \cos 4,504) = 0,318 \text{ m}
\]
\[
K = Ls - \frac{40 \times Rc^2}{40 \times 318^2} - Rc \sin \Theta s 
\quad \text{..................................................................................................................(9)}
\]
\[
K = 50 - \frac{40 \times 318^2}{40 \times 318^2} - 318 \sin 4,504 = 24,996 \text{ m}
\]

Calculate the value of the Distance from P1 to the circle (Es) and the Tangent Length from point P1 to the meeting point of the spiral tangent (TS) or the meeting point of the spiral to the tangent (ST).
\[
336,43 < 353,71 \quad \text{...(OK)}
\]
\[
Es = (Rc + P) \sec \frac{1}{2} \beta - Rc 
\quad \text{..................................................................................................................(10)}
\]
\[
Es = (318 + 0,328) \sec \frac{1}{2} 20 - 318 = 5,239 \text{ m}
\]
\[
TS = (Rc + P) \tan \frac{1}{2} \beta + k 
\quad \text{..................................................................................................................(11)}
\]
\[
TS = (318+0,328) \tan \frac{1}{2} \times 20 + 25 = 81,129 \text{ m}
\]

Next, calculate the relative slope with the known road width (L), the length of the spiral curve (Ls), and the coefficient value (e).
\[
= L \frac{(e+en) \times B}{L} 
\quad \text{..................................................................................................................(12)}
\]
\[
= 3,75 \frac{(0,02+0,059)}{50} = 0,005925
\]

After performing the calculations above, the results of the curve are as follows, visualized based on calculations in the 2D AutoCAD® applications.
4.2. Superelevation Diagram

Based on the horizontal curve that has been visualized in the figure above, a superelevation diagram is then made as follows.

4.3. Vertical Alignment

Vertical alignment was visualized on the 20.1 km section of Jalan Raya Wirosari Semarang to Ungaran Square with manual calculations and using autoCAD® 2D. The maximum grade for expressways on flat terrain is 4%, according to Table 5-48 (page 143) (Ditjen Bina Marga, 2021).
slope (\(g_1\) and \(g_2\)), the algebraic difference of the road's slope (A), and the vertical curvature length (L) with the following calculations.

\[
g_1 = \frac{\text{ev. PPV- ev. Awal}}{25.00 - 25.00} \times 100\% \tag{13}
\]

\[
g_1 = \frac{15,000 - 15,000}{25.00 - 25.00} \times 100\% = 0\%
\]

\[
g_2 = \frac{\text{Sta. PPV-Sta. Awal}}{26.00 - 25.00} \times 100\% \tag{14}
\]

\[
g_2 = \frac{17,000 - 15,000}{26.00 - 25.00} \times 100\% = 0.333\%
\]

\[
A = g_1 - g_2 = 0\% - 0.333\% = -0.333\% \text{ (lengkung cekung)}
\]

From the value of the design speed (VD) of 60 km/hour, the K value is 16 according to Figure 5-44 (p. 164) to determine the vertical arc length (L) as follows.

\[
L = K.A \tag{15}
\]

\[
L = 16 \times (-0.333\%) = 53.28 m
\]

From the vertical arc length (L) value, the vertical displacement value from the PPV point to the curved part can be determined by the following calculation method.

\[
Ev = \frac{AL}{800} \tag{16}
\]

\[
Ev = \frac{0.333 \times 53.28}{800} = 0.033 m
\]

\[
X = \frac{1}{4} \times L = \frac{1}{4} \times 53.28 = 13.32 m
\]

\[
Y = \frac{A \times X^2}{200 \times L} = \frac{0.333 \times 13.32^2}{200 \times 53.28} = 0.544 m
\]

5. Conclusion

Based on the geometric planning results for Jalan Raya Wirosari Semarang to Ungaran using the autoCAD® 2D method and calculations according to the Road Geometric Guidelines (Ditjen Bina Marga, 2021). which is applied to one part of the road on flat terrain. The design speed value (Vd) is set at 60 km/hour with a horizontal bend radius of 318 m, a maximum slope of 4%, and a maximum super-elevation value (e max) of 8%. From these design criteria, it is obtained that the horizontal curve is a spiral circle spiral with a circular arc length of 161.007 m, then the results of the calculation of the vertical alignment of one of the concave curved PPV types with the acquisition of a length value (L) of 53.28 m

Bibliography


Sukalkar, V. G., & Pawar, K. (2022). A Study and Design of Two Lane with Paved Shoulder in Green Filed Corridor, By Using Civil 3D.
